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1 and 17, surrounding the centrifuge rotor by annular
2 seals, 13 and 14, between 18 and bore 106 of housing
3 107. The concentrated carbon dioxide is removed
4 through a volute 9, discharging at 110.

5 The enriched methane is removed through a
6 port, 10, in the hollow shaft 2, and flows at 11 to
7 another part 110 of the process. Wall 6 in the shaft
8 separates flows 1 and 11. Auxiliary means to rotate
9 the shaft is shown at 111.

10 Fig. 2 shows another centrifuge which can be
11 used to decrease the concentration of carbon dioxide in
12 a gas mixture.

13 A gas mixture 1', enters the centrifuge 100'
14 via wall 110' and flows to a nozzle 2', which is
15 oriented in a generally tangential direction to a
16 cylindrical rotor 18'. The gas mixture is expanded in
17 the nozzle to a high exit velocity at 3', in a
18 direction generally tangential to the rotor. The gas
19 flows through axial vanes 17', with turbine effect,
20 which support the rotor from a shaft 16'. Nozzle 2' is
21 radially offset relative to rotary shaft 16'. The
22 rotor acquires the circumferential velocity component
23 of the entering gas.

24 The heavier carbon dioxide is concentrated by
25 the centrifugal force at centrifuge outer radius zone
26 4', near outer wall of the rotor 104'. The lighter

1 methane is concentrated at the inner radius zone 5'
2 near the surface of shaft 16' of the rotor. The
3 concentrated carbon dioxide stream flows through outlet
4 passage 7' increasing its pressure. The flow is then
5 accelerated through a nozzle 8, adding more torque to
6 the rotor to overcome windage and friction losses. The
7 concentrated carbon dioxide stream is removed through a
8 volute 9', discharging at 209'.

9 The concentrated methane stream flows into an
10 outlet scoop 10', which faces in generally tangential
11 relation to the circumferential flow direction to
12 remove a produced and concentrated lighter gas such as
13 methane, from the cylinder. The velocity is converted
14 to pressure by the passage 11', which has an increasing
15 flow area within wall 111' to diffuse the velocity and
16 recover the velocity head as increased pressure at 12',
17 and delivered at 300 to process 301. The concentrated
18 methane is removed through another volute 12' at the
19 outer side or end of 111'.

20 The rotor is supported by annular bearings
21 13' located between the shaft 16 and bores in end walls
22 110' and 111'. If sufficient pressure drop is
23 available between 1' and 3', the shaft may be totally
24 enclosed; otherwise, a seal is incorporated in the
25 structure 13', and a power source 301~~is~~ is provided to
26 rotate the centrifuge at desired speed.

1 The pressure within the rotor 18' is isolated
2 by annular seals 14 and 15 from the low pressure on the
3 outer side 19' of the rotor, which is required to
4 minimize frictional losses at the high speed of the
5 rotor. The concentrated CO₂ in the volute 9', is
6 isolated from the pressure within the rotor 18', and
7 the pressure at zone 19' surrounding the rotor, by
8 seals 14' and 15'.

9 Fig. 5 shows another centrifuge which can be
10 used to decrease the concentration of carbon dioxide in
11 a gas mixture.

12 A gas mixture ^{1"}~~1~~, enters the centrifuge ^{100"}~~104~~
13 via wall 110' and flows to a nozzle 2', which is
14 oriented in a generally tangential direction relative
15 to a cylindrical rotor ^{13"}~~18~~. The gas mixture is
16 expanded in the nozzle to a high exit velocity at 3'',
17 in a direction generally tangential to the cylindrical
18 rotor. The gas flows through axial vanes 17'', with
19 turbine effect, which support the rotor from a shaft
20 ^{16"}~~16~~. Nozzle ^{2"}~~2~~ is radially offset relative to rotary
21 shaft ^{16"}~~16~~. The rotor acquires the circumferential
22 velocity component of the entering gas.

23 The heavier carbon dioxide is concentrated by
24 the centrifugal force at centrifuge outer radius zone
25 ^{4"}~~4~~, near outer wall 104'' of the rotor. The lighter
26 methane is concentrated at the inner radius zone ~~5~~⁵

1 near the surface of shaft 16" of the rotor. The
2 concentrated heavier carbon dioxide stream flows
3 through outlet passage 7", increasing its pressure.
4 The flow is then accelerated through a nozzle 8",
5 adding more torque to the rotor to overcome windage and
6 friction losses. The concentrated carbon dioxide
7 stream is removed through a volute 9", discharging at
8 209".

9 The concentrated methane stream flows into
10 another outlet passage 10", whose inlet 10" is
11 located radially inward at the radial location 5"
12 where the lighter gas is concentrated. The
13 concentrated methane stream flows through the outlet
14 passage 10" increasing it's pressure. The flow is
15 then accelerated through a nozzle 8" adding more
16 torque to the rotor to overcome windage and friction
17 losses. The concentrated methane is removed through
18 another volute 9" discharging at 209".

19 The rotor is supported by annular bearings
20 13" located between the shaft 16" and bores in end
21 walls 110" and 111".

22 The pressure within the rotor 18" is
23 isolated by annular seals 14" and 15" from the low
24 pressure on the outer side 19" of the rotor, which is
25 required to minimize frictional losses at the high
26 speed of the rotor. Such seals seal off between 18"

1 and wall 110a'''. The concentrated CO₂ in the volute
2 9'', is isolated from the pressure within the rotor
3 18'' and the pressure at zone 19'' surrounding the
4 rotor, by seals 14'' and 15''.

5 To further concentrate the carbon dioxide
6 stream and the methane stream, the flows at ^{9''}~~9~~ and ²~~12~~
7 leaving the centrifuge from Fig. 5, can be introduced
8 to additional like centrifuges, i.e. a ''cascade'' of
9 centrifuges.. The cascade provides a method of
10 connecting many centrifuges together so as to amplify
11 the separation capacity and flow rate of a single unit.

12 The cascade is typically comprised of a
13 number of stages, the size of each stage being defined
14 by the amount of flow that must go through the cascade.
15 The amount of flow required is directly related to the
16 desired flow of the product (the stream comprised
17 mostly of the lighter gas) and its concentration. The
18 desired concentration, in turn, determines the number
19 of stages necessary. The product delivery end of the
20 cascade is called the ''top'' while the waste end is
21 called the ''bottom''.

22 The cascade is divided into two sections, the
23 ''stripper'' and the ''enricher''. The enricher
24 section is that between the feed point (where the
25 mixture comes in) and the top of the cascade, while the
26 stripper section is the section below the feed point.